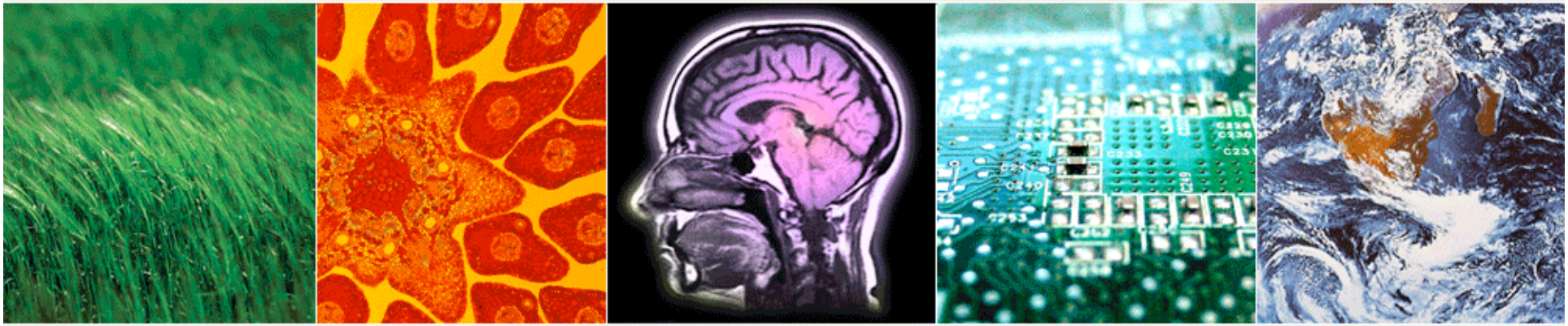
THE biodesign INSTITUTE
ARIZONA STATE UNIVERSITY

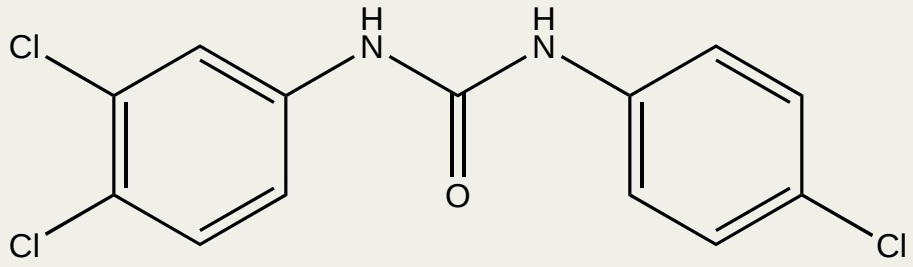
Center for Environmental Biotechnology

# Environmental Fate of Antimicrobials: 50 Years in 15 Minutes

Rolf Halden, PhD, PE

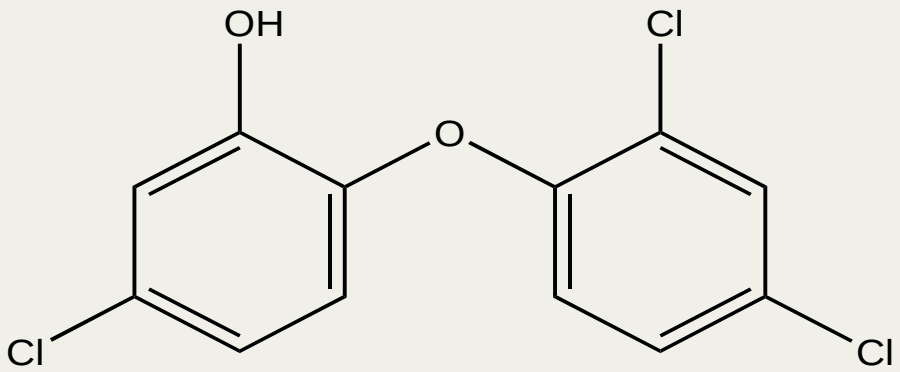
Pacific Southwest Organic Residuals Symposium
October 1-2, 2008, University of California at Davis






**Triclocarban (TCC)**

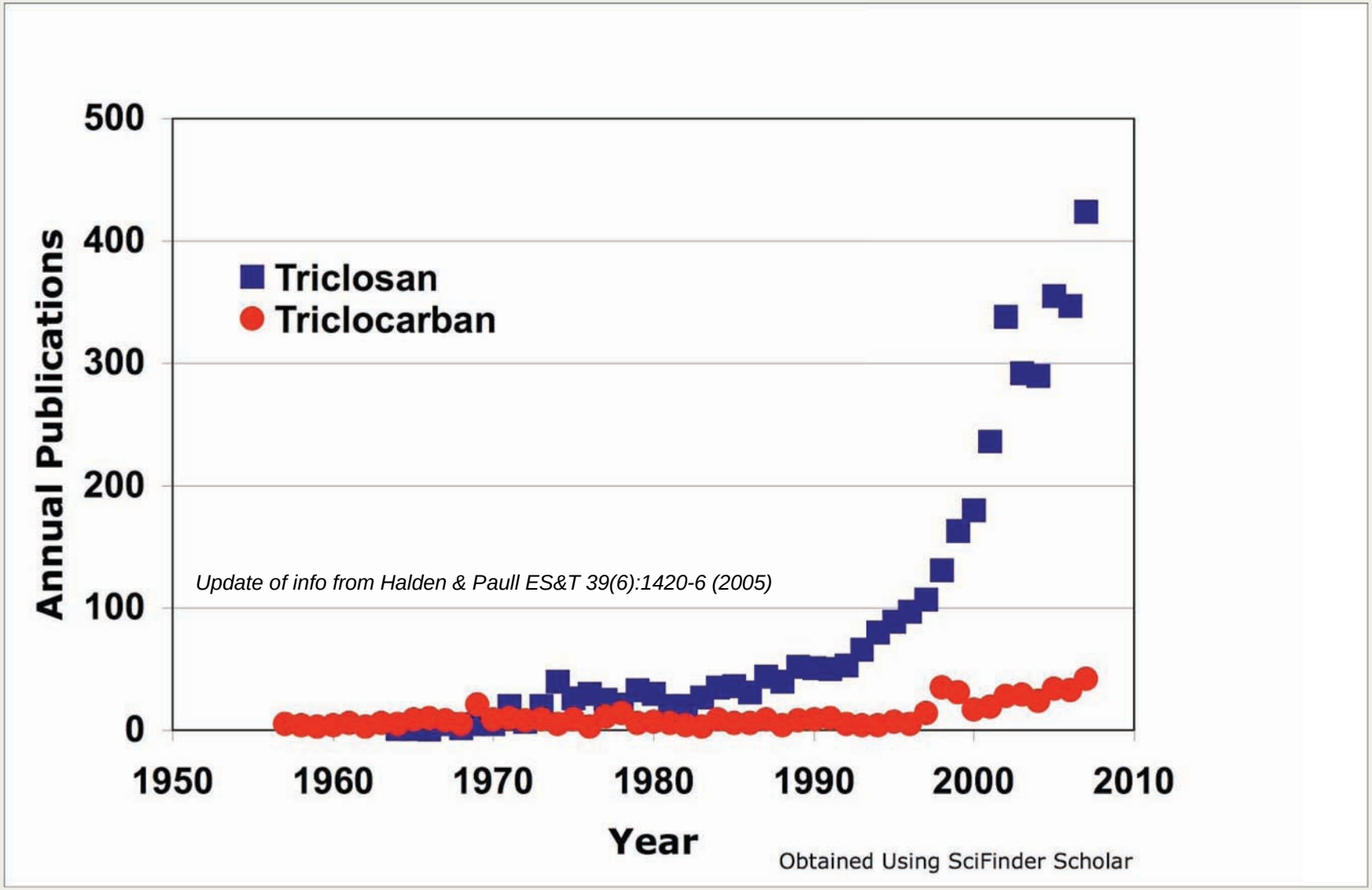
# 1957




**Triclosan (TCS)**

# 1964

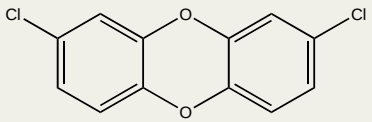
# Publishing Activity



## Environmental and Human Health Concerns

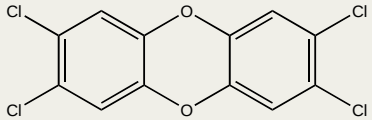
# Triclosan

Degradates
(including chloroform)




✓

Impurities




✓

Persistent Environmental Contaminant
✓

Cross-resistance to Antibiotics
✓

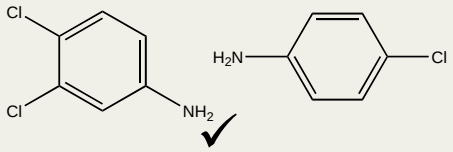
Bioaccumulation
✓

~~Acts as Carcinogen, Mutagen or Teratogen~~

Endocrine Disruption
✓

## Environmental and Human Health Concerns

Degradates




✓

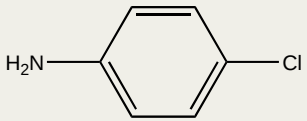
Persistent Environmental Contaminant

✓

Cross-resistance to Antibiotics

?

Impurities




? ✓

# Triclocarban

Bioaccumulation

? ✓

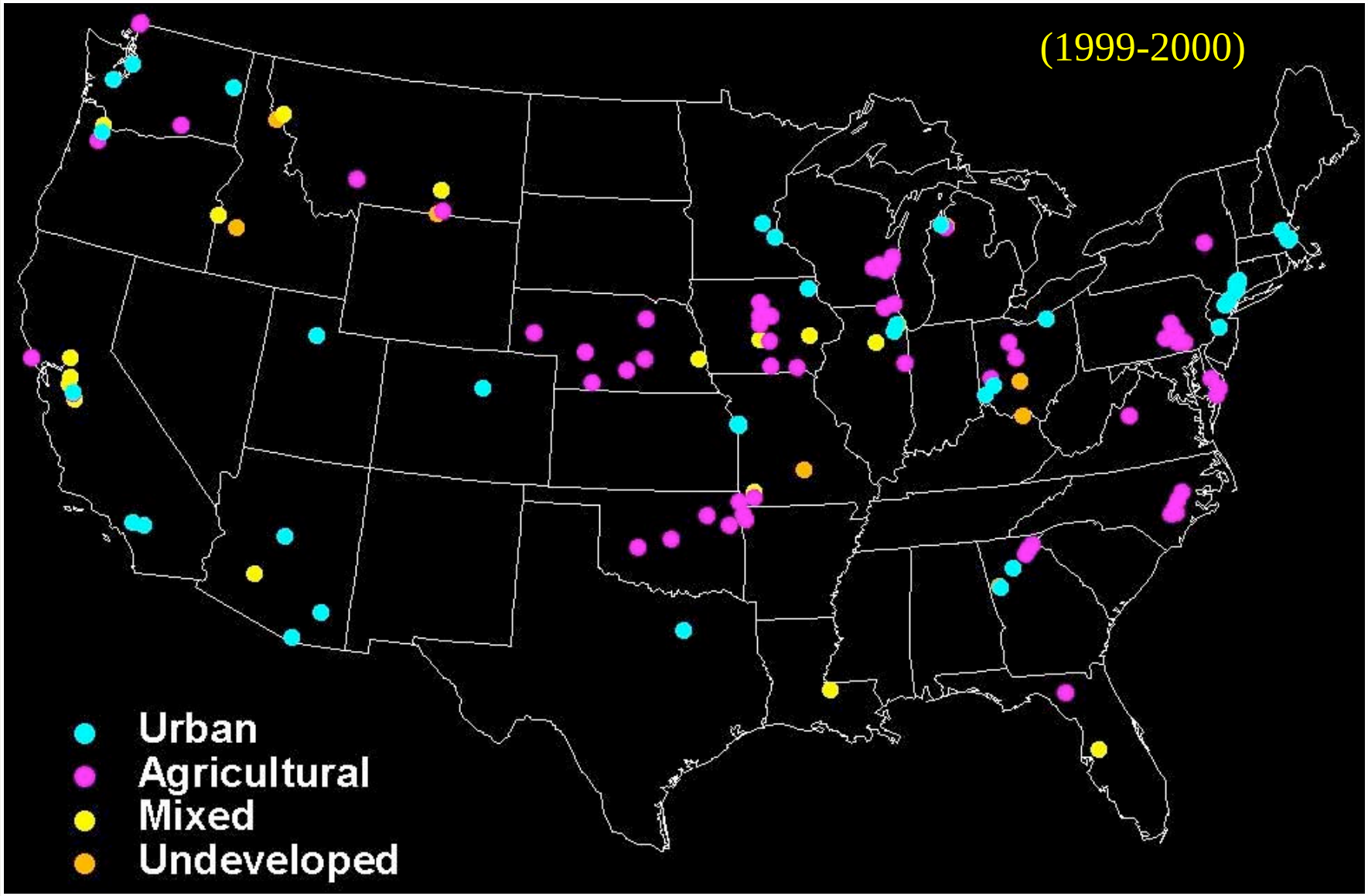
Acts as Carcinogen, Mutagen or Teratogen

(Indirectly through metabolites) ?

Endocrine Disruption

✓

# USGS Stream Monitoring Network



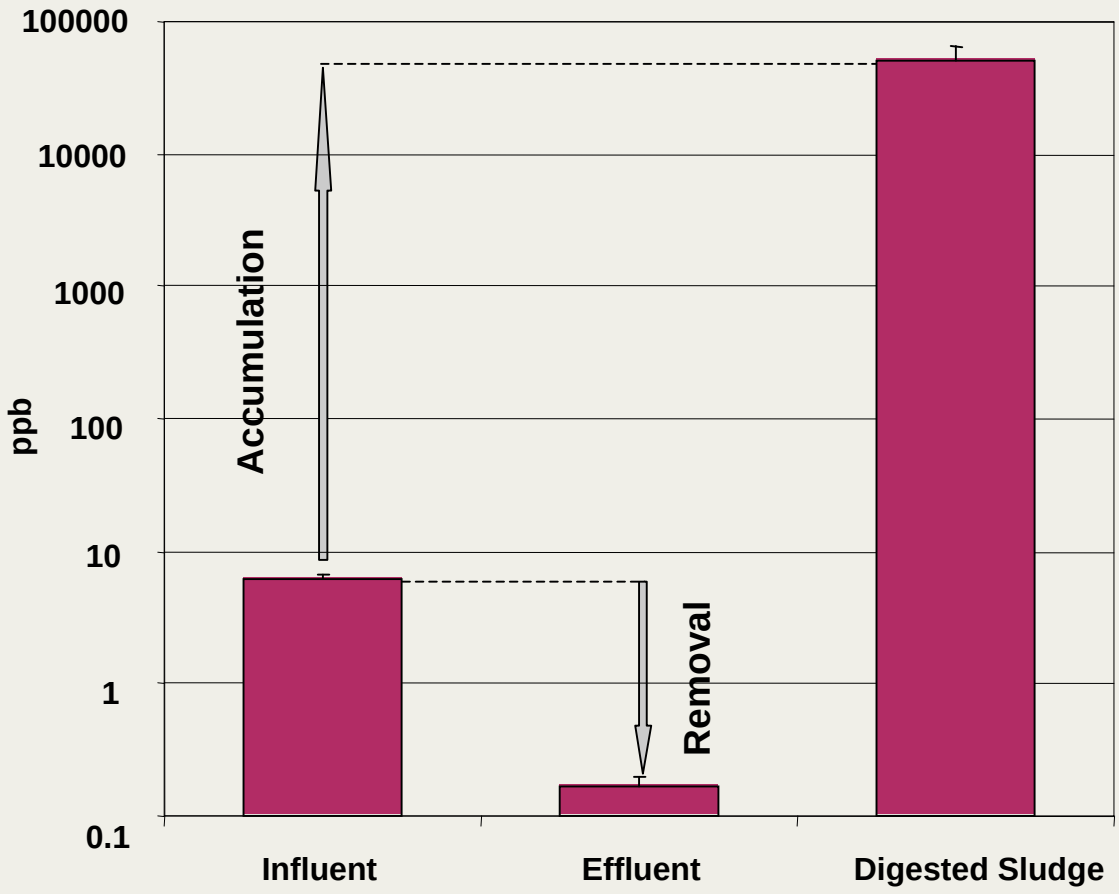

Source: *Kolpin et al. USGS 2002, ES&T 36:1202-1211*

# Wastewater Treatment Plants are Principal Sources of Antimicrobials in the U.S. Environment

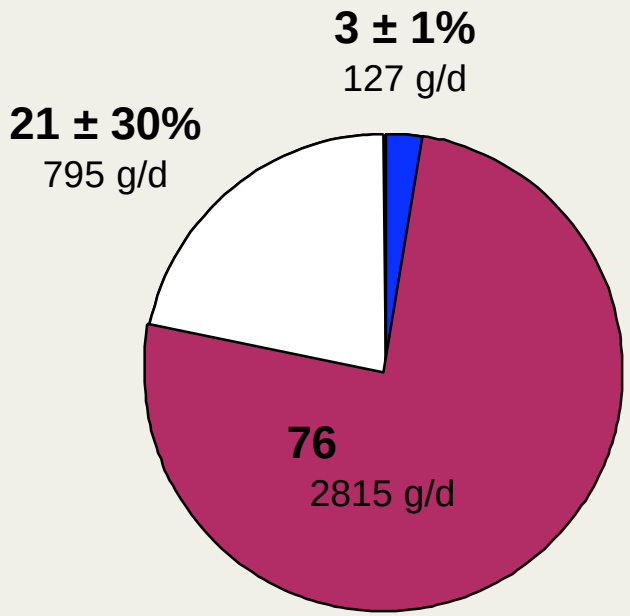
- Activated sludge WWTP
- 600 ML/D (180 MGD)
- Population served: 1.3 M

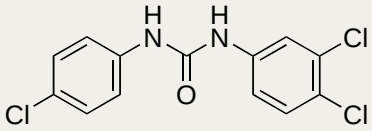
*Heidler et al. ES&T 40:3634 9 (2006)*

# Accumulation of TCC in Digested Sludge During Wastewater Treatment



# Fate of Triclocarban During Activated Sludge Treatment

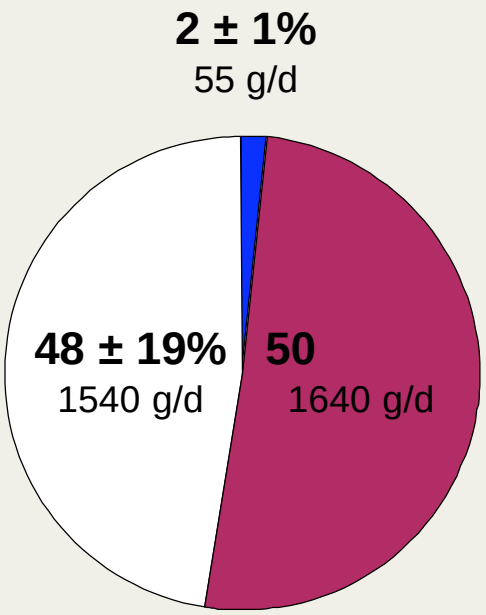


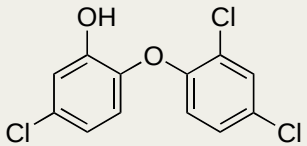




Triclocarban (TCC)

- Mass in effluent
- Mass in sludge
- Mass transformed/lost

# Fate of Triclosan in Activated Sludge WWTP

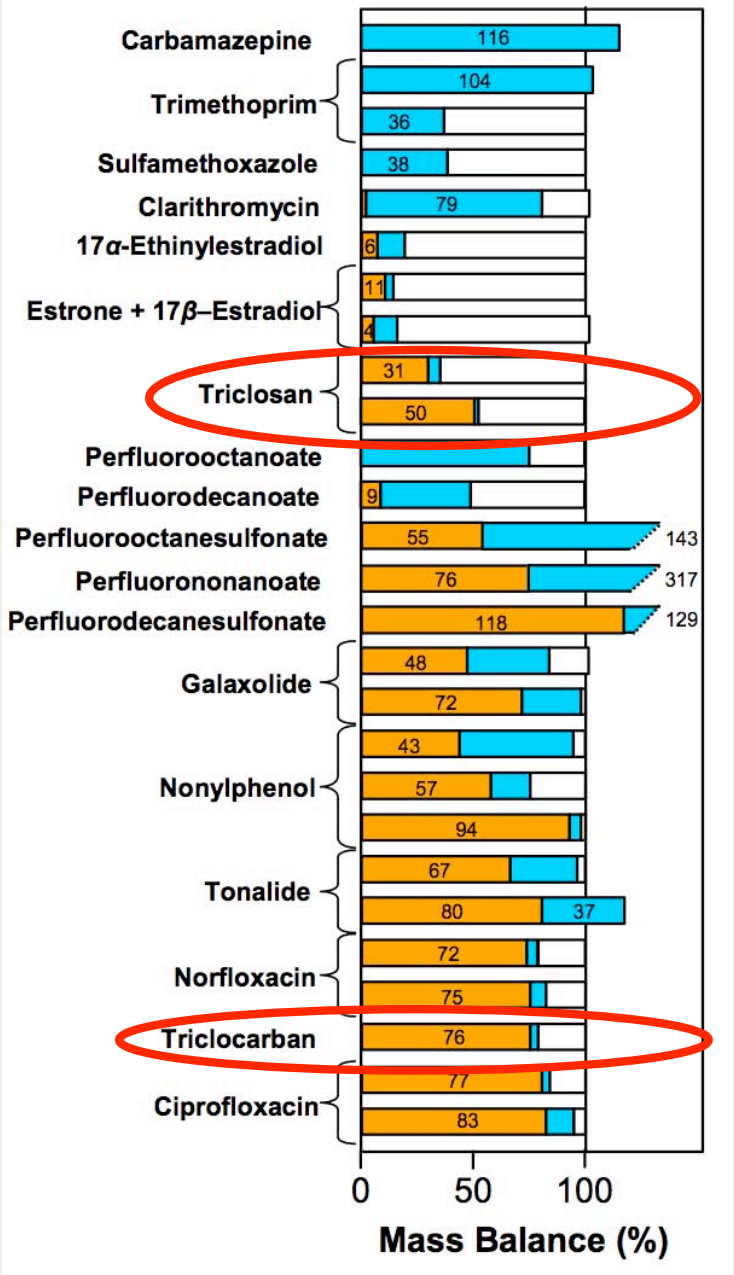


Triclosan (TCS)

- Mass in effluent
- Mass in sludge
- Mass transformed/lost

# Meta-Analysis of Mass Balances




*Heidler & Halden ES&T 42(17):6324-6332 (2008)*

## Triclosan & triclocarban can serve as surrogates for multiple issues

- Personal care products
- Pharmaceuticals
- Pesticides
- Endocrine disruptors
- Persistent halogenated aromatic compounds
- Promoters of antimicrobial resistance, cross-resistance, and multiple drug resistance
- Modulators and stressors of microbial communities
- Pollutants of aquatic & terrestrial environments
- Others

*Halden (Unpublished)*

# Nationwide Data of PPCPs in Biosolids

- 110 Wastewater treatment facilities
- 30+ U.S. States
- 70+ PPCPs examined
- Measurements validated by independent certified laboratory
- Triclocarban identified as the most abundant contaminant
- Triclosan identified as the second most abundant contaminant
- Together, TCC and TCS contributed >50% of the total mass of PPCPs targeted for analysis in biosolids
- TCC and TCS had the most unfavorable risk ratios (concentration in biosolids/EC50 values of most sensitive organisms)

  (TCC and TCS have no proven benefit for use in consumer products)

=> Removal of TCC/TCS-containing consumer products from the market would reduce by more than half the current PPCP loading to U.S. soils and associated risks from biosolids applications

*McClellan and Halden (In internal review)*

# Analysis of Environmental Occurrence Data Vis-a-Vis Toxic Threshold Levels of Susceptible Organisms

- TCC &TCS occur nationwide in:
  - raw sewage (1.86 – 26.8 µg/L for TCS; 0.4 – 50 µg/L for TCC)
  - sewage treatment plant effluent (0.027 – 2.7 µg/L for TCS; 0.1 – 6 µg/L for TCC)
  - surface waters (<2.3 µg/L for TCS; typically <0.25 µg/L; up to 6.75 µg/L of TCC in sewage impacted streams)
  - biosolids (90 – 32,900 µg/kg for TCS; 3,050 – 51,000 µg/kg for TCC)
  - sediments (up to 53,000 µg/kg for TCS; up to 24,000 µg/kg for TCC)
- Environmental occurrences in some locales exceed the threshold values of susceptible organisms:
  - algae in U.S. surface waters (TCS)
  - crustaceans in U.S. aquatic environments (TCC)
  - concentrations in some locations in U.S. streams approach levels that are toxic to fish (TCC)
  - microorganisms (the targets of antimicrobial agent usage) are orders of magnitude more tolerant to TCS and TCC than sensitive aquatic and terrestrial non-target receptor organisms (algae, crustaceans, fish etc.)

# Persistence & Fate

- TCC & TCS are persistent, particularly under anaerobic conditions
  - can persist for decades in aquatic sediments*
- PPCPs in the environment: dilution is not the solution
  - ppb $_{\text{WWTP Influent}}$ => ppt $_{\text{WWTP Effluent}}$ => **ppm** **Biosolids, Sediments, Earthworms**

** Miller et al. 2008 ES&T 42:4570-76*

# State of Science

**Triclosan & Triclocarban**

- **have no proven benefit for most current uses (according to 2005 FDA panel)**
  - antimicrobials can save lives but TCC & TCS containing consumer products do not
- >>1M lbs/year combined;  production up; >1,500 different products
- detectable in >50% of U.S. surface waters; ~400,000 lbs/year contained in sludge deposited on land
- toxic to aquatic biota at ng/L level
- accumulate in sludge, sediment and house dust to ppm levels (significant fraction of total organohalogen burden)
- bioaccumulate in algae and earthworms
- endocrine disrupting properties
- promote drug-resistance *in vitro*
- contain dioxins & carcinogenic impurities
- degrade to form additional carcinogens (e.g., chloroanilines)
- long environmental half-lives; years/decades in anaerobic environments
- detectable in fish, house dust, urine, blood from adults & fetuses and in 97% of U.S. breast milk samples

# Acknowledgements


**Contributors**

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